
(Editor's notes are provided for clarification and enhancement within the lesson learned. They will always appear as italicized words bordered by parentheses.)

Lessons Learned System Number: EXT-10-003

Lesson Date: August 18, 2010

Submitted By: John Carmack

Submitting Organization: Armadillo Aerospace

Title of Lesson Learned:

Parameter Validation – A Simple Input Error that Could Have Cost the Vehicle.

Abstract:

When entering or changing parameters prior to a test run or during a launch, it is always prudent to verify that the test parameters are within a specified reasonable range. This will eliminate the risk of someone who is unfamiliar with the software or parameters from inputting errant parameters or the operator using the wrong units. Failure to do so may result in vehicle loss.

Triggering Event:

The test of the day was to fly methane-Pixel to exercise some new propellant balancing systems. We are often tweaking the throttle level for ignition on various tests. *(The throttle setting)* needs to be high enough to generate some chamber pressure, but low enough to prevent vehicle lift off. Changing engines, propellants, pressurization levels, or start procedures can require changes to *(the throttle setting)*.

For this test, 35% was deemed a reasonable level, so "ignitionThrottle 35" was added to the parameter file for the test. The problem was that "ignitionThrottle" is a floating point value in the range of 0.0 to 1.0, and it should have been entered as 0.35. I wouldn't have made that error, but it was completely understandable for someone else who hadn't actually written the code to do so.

(Immediately after sending the start command), the vehicle went to full throttle and started accelerating up, and it also started rotating fairly rapidly. *(The operator quickly shut the vehicle down)* but it still basically flew over the crane truck before swinging back on the tethers. It was a tense couple of minutes as the 1500 pound pendulum *(vehicle)* swung back and forth *(on the tether)*, but it didn't wind up whacking the crane boom.

It didn't take long to figure out the throttle issue, but the tipping was a mystery for a little while. The first thought was that we had a horrible propellant imbalance. It turned out that the control software was still keeping the gimbals locked in the center position, because the flight hadn't "started" yet.

This was a significant lesson, if it had been a free flight, we would have lost the vehicle.

Lesson(s) Learned:

1. Validate test parameters before flight. Requiring explicit min/max values with every parameter definition will force at least some thought to be given whenever a new parameter is added.
2. The correct software behavior is to fail to start if anything doesn't pass.

Recommendation(s):

1. When adding a new parameter, require explicit min/max values with every parameter definition.
2. Develop a preflight checklist to ensure test parameters are validated prior to flight.

Any questions regarding this lesson learned should be directed to the point of contact.

Point of Contact:

John Carmack
Armadillo Aerospace
johnc@idsoftware.com